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# Provincial Report

## Chemistry 30
## Grade 12 Diploma Examination

April 1984

# Student Evaluation

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# PREFACE

This report presents the provincial results of the Chemistry 30 Diploma Examination administered on January 30, 1984. During this first administration, the Chemistry 30 Diploma Examination was written by 5688 students. This report is intended to provide more information about the examination development process, the examination itself, and the examination results.

## ACKNOWLEDGMENTS

This first administration of the Chemistry 30 Diploma Examination was successful due to the concerted effort of all involved. Success would have been impossible without substantial contributions from many people, particularly the administrators, teachers, and students, who extended their full co-operation.

The technical expertise and advice received from the Examination Review Committee regarding design, development, and reporting have been particularly valuable in the implementation of this diploma examination. This Committee has representation from:

The Alberta Teachers' Association
The Conference of Alberta School Superintendents
The Universities Co-ordinating Council
The Public Colleges of Alberta
Alberta Education

The contribution of this group is gratefully acknowledged.

Lloyd E. Symyrozum
Director
Student Evaluation Branch

# CHAPTER 1

## Grade 12 Diploma Examinations Program

### Introduction

All Grade 12 students in Alberta are now required to write at least ONE diploma examination to receive a high school diploma. Mature students may receive credits for a Grade 12 course by writing the appropriate diploma examination. They are not required to be registered in the course. The Grade 12 Diploma Examinations Program, which is an integral part of the high school diploma requirements, is intended to develop and maintain excellence in educational standards through certification of academic achievement.

The Diploma Examinations Program consists of course-specific examinations that are based on the prescribed *Program of Studies for Senior High Schools* for the following Grade 12 courses: English 30, English 33, Social Studies 30, Mathematics 30, Biology 30, Chemistry 30, and Physics 30.

Alberta Education issues two distinct high school diplomas: the General High School Diploma and the Advanced High School Diploma.

### General High School Diploma

To earn a General High School Diploma, a student must obtain course credit in either English 30 or English 33, and obtain 100 credits distributed over courses as specified in the *Junior-Senior High School Handbook*. Some students who are working toward the general diploma may wish to obtain credits in other diploma examination courses (i.e., Social Studies 30, Mathematics 30, Biology 30, Chemistry 30, and Physics 30). To obtain credits in these courses, a student must also write the appropriate diploma examination regardless of the type of diploma he wishes to receive.

### Advanced High School Diploma

The Advanced High School Diploma represents achievement in an academic program that includes language arts (English), social studies, mathematics, and science. To earn an Advanced High School Diploma, a student must satisfy the current course and credit requirements for a General High School Diploma, and obtain course credits in English 30, Social Studies 30, Mathematics 30, and ONE of Biology 30, Chemistry 30, or Physics 30.

### Awarding of Course Credits

*Grade 10 and Grade 11 Courses.* To obtain credits in Grade 10 (10-level) and Grade 11 (20-level) courses, a student must earn a final mark of 40% or better. A student who has achieved a mark of 50% or higher in a given course is eligible to take the next or higher-rank high school course in that sequence.

*Grade 12 Courses.* To obtain credit in a Grade 12 (30-level) course, a student must earn a final mark of 50% or better. To obtain credit in a Grade 12 diploma examination course, a student must write the appropriate diploma examination and attain a final blended mark of 50% or better. The final blended mark is made up of 50% of the mark awarded by the school and 50% of the diploma examination mark. For example, a student taking Chemistry 30 might have a mark of 45% from his school and a mark of 57% on the diploma examination. This student would earn credits for Chemistry 30 because his final mark would be 51%, which is the average of the school and examination marks. For mature students who do not have a school mark or who have a school mark lower than the examination mark, the examination mark is the final mark.

## Transitional Provisions

During the 1983-84 school year, Alberta Education will recognize all course credits earned prior to September 1, 1983, for the purpose of awarding the General High School Diploma.

Students who have completed partial requirements for the Advanced High School Diploma prior to September 1, 1983, and who are enrolled in Grade 12 courses during the 1983-84 school year, may apply any of the previously completed required diploma examination subjects toward a diploma, provided they have earned a final course mark of 50% or better in each subject.

## Award of Excellence

When candidates for an Advanced High School Diploma obtain a final average of 80% or higher on the four required diploma examination courses with not less than 65% in any one of these four required courses, they receive an Award of Excellence. This Award of Excellence is noted on the student's Advanced High School Diploma. When a student writes two or three of the diploma examinations in Biology 30, Chemistry 30, and Physics 30, the highest of these final course marks is used for diploma purposes and in the calculation of the average for the Award of Excellence.

# CHAPTER 2

## Description of the Examination

This chapter outlines the procedures that were followed during examination development and describes the structure and content of the examination.

### Examination Development

There were three stages in the development of the January 1984 Chemistry 30 Diploma Examination: preparation of curriculum specifications, development of questions, and selection of questions for the final copy.

1. Curriculum Specifications

   The Curriculum Branch of Alberta Education prepared curriculum specifications based on the topical outline of the Chemistry 30 core described in the *Program of Studies for Senior High Schools*. In these specifications, weightings were assigned to each major course content area and to specific topics outlined in the *Program of Studies*. These weightings were based on the emphasis that each topic was to receive in the Chemistry 30 program. The curriculum specifications were distributed to all school jurisdictions in the province.

   Topic statements upon which specific questions were based, along with sample questions for each topic, are given in this chapter.

2. Development of Questions

   Committees composed of teachers and Student Evaluation Branch personnel constructed questions to reflect the content statements listed in the curriculum specifications. The questions were field-tested and revisions were made on the basis of teacher recommendations and the field test results.

3. Final Copy

   A test development specialist, assisted by groups of classroom teachers, built the examination from suitable questions. These committees selected questions from various content areas, so that each area received the emphasis recommended in the curriculum specifications. An Examination Review Committee checked the proposed examination for content validity, accuracy, and technical merit, and further changes were made in accordance with their recommendations.

## Examination Description

On the January 1984 Chemistry 30 Diploma Examination, each content area received the following emphasis:

| Content Area | Emphasis in % of the Total Examination Mark |
|---|---|
| Chemical Energetics | 36 |
| Acids and Bases | 30 |
| Oxidation-Reduction | 34 |

To the extent that paper-and-pencil testing permitted, the Chemistry 30 Diploma Examination assessed the application of the scientific process skills of controlling variables, interpreting data, defining in operational terms, inferring, and predicting. The questions that are readily identified with specific process skills are listed below.

| Process Skill | Multiple-Choice Question |
|---|---|
| Controlling variables | 17 |
| Interpreting data | 8, 35 |
| Defining | 21 |
| Inferring | 26 |
| Predicting | 7, 48 |

Understandably, the experience gained by direct, hands-on activities are difficult to measure outside a laboratory situation and should therefore be reflected in student performance as evaluated by the teacher.

Subject matter in the attitudinal and psychomotor components of the program was excluded from the diploma examination.

The time allotted for the Chemistry 30 Diploma Examination was two and one-half hours. The examination consisted of both multiple-choice questions (worth 80% of the total examination mark) and written-response questions (worth 20% of the total examination mark). There were 55 multiple-choice questions worth one mark each and three written-response questions worth a total of 15 marks. There was one written-response question on each of the three core topics of the examination.

The classification of examination questions according to subject matter area and taxonomic level is presented in Table 1.

Table 1

January 1984 Chemistry 30 Diploma Examination Blueprint

| Subject Matter | Question by Taxonomic Level | | | Examination Emphasis |
|---|---|---|---|---|
| | Knowledge | Application and Understanding | Higher Mental Activities | |
| Chemical Energetics | 1,2,3,4,5,14 | 6,8,9,11,12,13,<br>15,16,18<br>[1] | 7,10,17 | 36% |
| Acids and Bases | 19,20,21,22,<br>23,24,29,31,<br>34 | 25,26,28,30,33,<br>36<br>[2] | 27,32,35 | 30% |
| Oxidation - Reduction | 37,39,46,47,<br>50,51,52,53,<br>55 | 38,40,41,42,43,<br>44,45,48,54<br>[3] | 49 | 34% |
| Examination Emphasis | 35% | 50% | 15% | 100% |

Note: Numbers in brackets [ ] indicate the written-response questions.

## Explanation of Blueprint Thought Levels

### 1. Knowledge

Knowledge is defined as including those behaviors and examination situations that emphasize the remembering, either by recognition or recall, of ideas, material, or phenomena. Incorporated at this level is knowledge of terminology, specific facts (dates, events, persons, etc.), conventions, classifications and categories, criteria, methods of inquiry, principles and generalizations, and theories and structures.

2. Application and Understanding

Application requires the student to apply an appropriate abstraction (theory, principle, idea, method) to a new situation.

Understanding refers to responses that represent a comprehension of the literal message contained in a communication. This means that the student is able to translate, interpret, or extrapolate. Translation refers to the ability to put a communication into another language. Interpretation involves the reordering of ideas (inferences, generalizations, or summaries). Extrapolation includes estimating or predicting based on an understanding of trends or tendencies.

3. Higher Mental Activities

Included in higher mental activities are the processes of analysis, synthesis, and evaluation. Analysis involves the ability to recognize unstated assumptions, to distinguish facts from hypotheses, to distinguish a conclusion from statements that support it, to recognize which facts or assumptions are essential to a main thesis or to the argument in support of that thesis, to distinguish cause-effect relationships from other sequential relationships, and to recognize the point of view of a writer.

Synthesis involves the production of a unique communication, the ability to propose ways of testing hypotheses, the ability to design an experiment, the ability to formulate and modify hypotheses, and the ability to make generalizations.

Evaluation is defined as the making of judgments about the value of ideas, solutions, and methods. It involves the use of criteria as well as standards for appraising the extent to which details are accurate, effective, economical, or satisfying. Evaluation involves the ability to apply given criteria to judgments of work done, to indicate logical fallacies in arguments, and to compare major theories and generalizations.

The taxonomic classification of examination questions may depend on the manner in which the content has been covered in the classroom. A question that is an application question for one class may be a knowledge question for another class.

Questions requiring knowledge of and skill in the processes of science were included throughout the examination and were not associated with any specific topic or thought level.

## Description of Subject Matter Areas and Sample Multiple-Choice Questions

The topics that were tested within each subject matter area are listed and sample questions from the test are provided. The correct response for each question is identified by an asterisk and the percentage of students selecting each response is given.

## 1. Chemical Energetics

Questions 1 to 18 in the multiple-choice portion of the examination are related to Chemical Energetics. The major concepts involved in this area are:

- each substance has a definite and characteristic heat content or enthalpy
- changes in matter involve a change in energy

The following example requires students to recognize the effect of an exothermic reaction on its surroundings.

Question 8:

When a piece of strontium is dropped into water, the temperature of the water increases. The statement that correctly interprets this information is

Student Responses

| | | |
|---|---|---|
| 12.6% | A. | $Sr(s) + 2H_2O(\ell) + 434\ kJ \rightarrow Sr(OH)_2(aq) + H_2(g)$ |
| 15.3% | B. | heat is absorbed by the reaction |
| 18.5% | C. | the reaction is endothermic |
| 53.5% | *D. | the reactants have more potential energy than do the products |
| 0.1% | | no response |

The following example requires students to apply methods of calculating heat energy involved in a chemical reaction based on a given number of moles of a reactant.

Question 11:

If 4.00 mol of $NH_3(g)$ are decomposed according to the equation $NH_3(g) + 46.2\ kJ \rightarrow \frac{1}{2}N_2(g) + \frac{3}{2}H_2(g)$, the heat absorbed is

Student Responses

| | | |
|---|---|---|
| 11.3% | A. | 11.6 kJ |
| 13.7% | B. | 46.2 kJ |
| 4.7% | C. | 92.4 kJ |
| 70.2% | *D. | 185 kJ |
| 0.1% | | no response |

## 2. Acids and Bases

Questions 19 to 36 are based on the following major concepts:

- acids and bases can be defined in different ways
- the relative acidity of a solution can be measured
- acid-base reactions involve an exchange of protons

The following example requires a knowledge of the Arrhenius definition of an acid.

Question 19:

The Arrhenius definition of an acid states that an acid

Student Responses

| | | |
|---|---|---|
| 4.8% | A. | acts as a proton acceptor |
| 27.9% | B. | acts as a proton donor |
| 7.1% | C. | releases hydroxide ions in solution |
| 60.1% | *D. | releases hydrogen ions in solution |
| 0.0% | | no response |

The following example requires students to recognize the quantitative relationship between an acid in solution and the hydroxide ion concentration in that solution. Students must apply methods of calculating the hydroxide ion concentration.

Question 28:

In a 0.20 mol/L $HNO_3$(aq) solution, the concentration of the hydroxide ion is

Student Responses

| | | |
|---|---|---|
| 77.7% | *A. | $5.0 \times 10^{-14}$ mol/L |
| 10.5% | B. | $2.0 \times 10^{-14}$ mol/L |
| 7.1% | C. | $5.0 \times 10^{-7}$ mol/L |
| 4.6% | D. | $1.0 \times 10^{-7}$ mol/L |
| 0.2% | | no response |

3. Oxidation-Reduction

Questions 37 to 55 are based on the following concepts:

- redox reactions involve an exchange of electrons
- in a redox reaction the electron loss and gain must balance
- the electrical potential of a redox reaction can be predicted and measured
- redox reactions involve electrical energy

The following example requires knowledge of the terms associated with oxidation-reduction reactions.

Question 37:

In an oxidation-reduction reaction,

Student Responses

| | | |
|---|---|---|
| 17.3% | A. | the species that is oxidized gains electrons |
| 59.5% | *B. | reducing agents lose electrons |
| 10.8% | C. | oxidizing agents undergo oxidation |
| 12.4% | D. | all oxidizing agents are on one side of the equation |
| 0.0% | | no response |

The following example requires students to identify and analyse the principles involved with the spontaneity of a redox reaction.

Question 49:

The ion that will oxidize $Cu(s)$ to $Cu^{2+}(aq)$, but will not oxidize $Br^{-}(aq)$ to $Br_2(\ell)$, is

Student Responses

| | | |
|---|---|---|
| 8.1% | A. | $Zn^{2+}(aq)$ |
| 8.9% | B. | $2H^{+}(aq)$ |
| 5.1% | C. | $Co^{2+}(aq)$ |
| 77.7% | *D. | $Ag^{+}(aq)$ |
| 0.2% | | no response |

### 4. Scientific Process Skills

The process skills covered by the examination were:

Inferring - the process of arriving at a tentative explanation or conclusion based on direct or indirect observations.

Predicting - the process of formulating a specific forecast of what a future observation will be. Predicting often involves interpolating and extrapolating.

Controlling Variables - the process of deciding which variables or factors will influence the outcome of an experiment, situation, or event. In an experimental situation, the variables of interest are free to vary in response to variables over which the experimenter exercises control. Controlled variables are allowed to take on specific values.

Interpreting Data - the process of recognizing patterns in data, identifying relationships between variables, and forming generalizations.

Defining in Operational Terms - the process of giving definitions in terms of how things behave.

The following example requires students to relate an experimental procedure to a testable prediction.

Question 7:

Use the following information to answer question 7.

A student follows the procedure outlined below:

I Record the temperature of 30 mL of water in a beaker.
II Add a pellet of NaOH(s) to the water.
III Stir until there is no solid left.
IV Record the final temperature of the water.

Which prediction could be tested with the data collected by ONLY these four steps?

Student Responses

| | | |
|---|---|---|
| 62.8% | *A. | An exothermic reaction will occur when NaOH(s) is added to $H_2O(\ell)$. |
| 7.7% | B. | The molar heat of reaction for NaOH(s) with $H_2O(\ell)$ will be -28.4 kJ/mol. |
| 11.5% | C. | The solubility of NaOH(s) will decrease as the temperature of the water increases. |
| 17.8% | D. | The temperature change will be greater if more NaOH(s) is used. |
| 0.2% | | no response |

## Written-Response Questions

In this section, students were expected to communicate their answers clearly and identify the steps in their solutions. All answers were to give the correct number of significant figures in calculations and include appropriate units.

Each written-response question from the examination is given on the following pages with an appropriate answer. The total possible marks for each question is given, along with the average number of marks awarded. The distribution of marks awarded to students for each written-response question is shown in Table 6, Chapter 3.

Question 1 requires students to apply the principles involved in calorimetry and to use hypothetical data to calculate heats of reaction and formation.

$C_3H_7OH(\ell)$ was completely burned to $CO_2(g)$ and $H_2O(g)$ in the bomb of a bomb calorimeter. The data obtained are tabulated below:

| | |
|---|---|
| Volume of water surrounding the bomb | 750 mL |
| Temperature of water surrounding the bomb before the reaction | 20.5°C |
| Temperature of water surrounding the bomb after the reaction | 38.2°C |
| Mass of $C_3H_7OH(\ell)$ burned | 30.1 g |

a. Calculate the heat gained by the water surrounding the bomb.

Key: heat gained $= mc\Delta t$

$= 0.750 \text{ kg} \times 4.19 \text{ kJ/kg}\bullet{}^\circ\text{C} \times 17.7{}^\circ\text{C}$

$= 55.6 \text{ kJ}$

b. Calculate the molar heat of reaction for $C_3H_7OH(\ell)$.

Key:

$$\text{moles of } C_3H_7OH = \frac{30.1 \text{ g}}{60.11 \text{ g/mol}}$$

$$= 0.501 \text{ mol}$$

$$\text{heat per mole of } C_3H_7OH = \frac{55.6 \text{ kJ}}{0.501 \text{ mol}}$$

$$= -111 \text{ kJ/mol}$$

c. Write a balanced equation for the reaction.

Key: $2C_3H_7OH(\ell) + 9O_2(g) \rightarrow 6CO_2(g) + 8H_2O(g)$

d. Calculate the $\Delta H$ for the equation in part c.

Key: $\Delta H$ = mole x heat per mole

= 2 mol x -111 kJ/mol

= -222 kJ

e. Calculate the molar heat of formation of $C_3H_7OH(\ell)$.

Key: $2C_3H_7OH(\ell) + 9O_2(g) \rightarrow 6CO_2(g) + 8H_2O(g)$

$$\Delta H = -222 \text{ kJ} = [6(-393.5) \text{ kJ} + 8(-241.8) \text{ kJ}] - 2\Delta H_f$$

$$\Delta H_f = \frac{[6(-393.5) + 8(-241.8)] \text{ kJ} + 222 \text{ kJ}}{2}$$

$$= \frac{(-4295.4 + 222) \text{ kJ}}{2}$$

$$= \frac{-4073.4}{2}$$

$$= -2037 \text{ kJ/mol}$$

It was possible to score 7 marks for this question. The average number of marks awarded to students was 2.3.

Question 2 involves a simple acid-base titration.

A 25.0 mL sample of 0.145 mol/L acetic acid was titrated to the endpoint with a 0.250 mol/L sodium hydroxide solution using phenolphthalein as an indicator.

a. Write the Brønsted-Lowry net ionic equation for the reaction.

Key: $CH_3COOH(aq) + OH^-(aq) \rightleftharpoons H_2O(\ell) + CH_3COO^-(aq)$

b. Determine the volume of sodium hydroxide required.

Key: moles of acid = (0.0250 L)(0.145 mol/L)

= 0.003 63 mol

$$\text{volume of base} = \frac{\text{moles of acid}}{\text{molarity of base}}$$

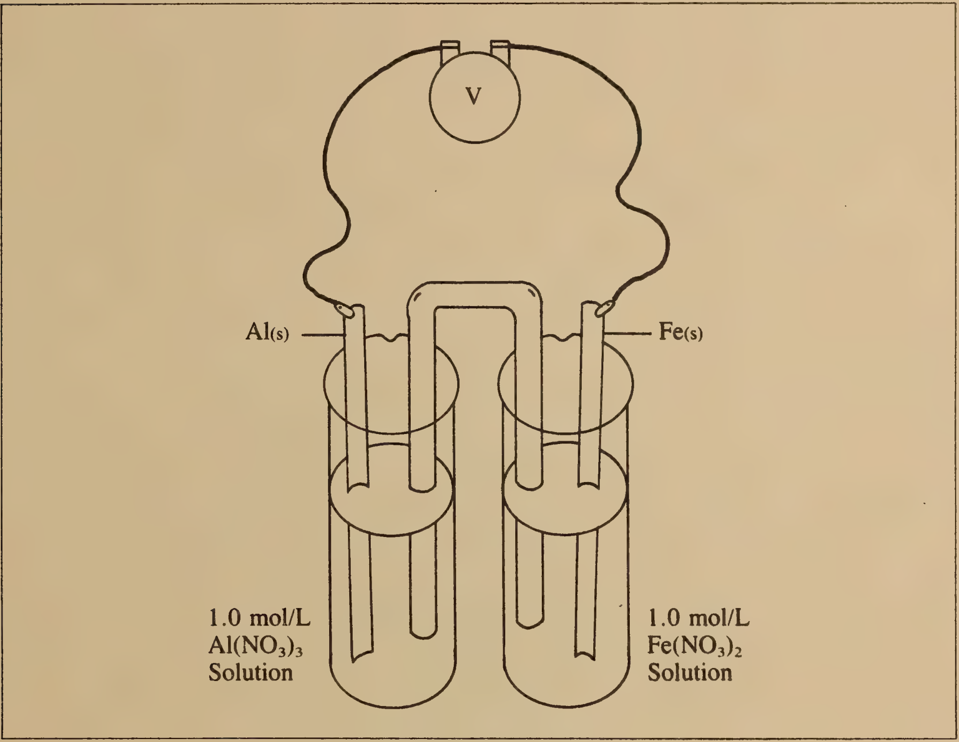
$$= \frac{0.003\ 63 \text{ mol}}{0.250 \text{ mol/L}}$$

= 0.0145 L or 14.5 mL

It was possible to score 3 marks for this question. The average number of marks awarded to students was 1.7.

Question 3 requires students to apply the principles involved in the operation of an electrochemical cell.

Use the following information to answer question 3.



a. Predict the voltmeter reading assuming standard conditions and negligible internal resistance.

Key: $Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$ $E° = -0.41$ V

$Al(s) \rightarrow Al^{3+}(aq) + 3e^-$ $E° = +1.66$ V

$3Fe^{2+}(aq) + 2Al(s) \rightarrow 3Fe(s) + 2Al^{3+}(aq)$ $E°_{net} = +1.25$ V

b. Write the equation for the half-reaction that would occur at the iron electrode.

Key: $Fe^{2+}(aq) + 2e^- \rightarrow Fe(s)$

c. If 0.050 mol of electrons passes through the cell and the original mass of the aluminum electrode was 9.82 g, predict the final mass of the aluminum electrode.

Key: $Al(s) \rightarrow Al^{3+}(aq) + 3e^-$
? g 0.050 mol

$$\text{moles of Al} = 0.050 \text{ mol } e^- \times \frac{1 \text{ mol Al}}{3 \text{ mol } e^-}$$
$$= 0.017 \text{ mol}$$

$$\text{mass of Al} = 0.017 \text{ mol} \times 26.98 \text{ g/mol}$$
$$= 0.45 \text{ g}$$

$$\begin{array}{rl} \text{final mass Al} = & 9.82 \text{ g Al initially} \\ & \underline{-0.45 \text{ g}} \text{ Al reacted} \\ & 9.37 \text{ g Al remain} \end{array}$$

d. Predict which metal ion concentration would increase as the cell operates.

Key: $Al^{3+}(aq)$ would increase

It was possible to score 5 marks for this question. The average number of marks awarded to students was 1.9.

# CHAPTER 3

# Results

## Validity and Reliability

The content validity of the examination was established by the procedure for examination development outlined in Chapter 2. Each question was mapped to a specific topic statement defining some aspect of the curriculum. The Examination Review Committee evaluated each question, and the examination as a whole, for content validity.

The KR-20 coefficient for the multiple-choice portion of the examination was 0.88, and Cronbach's alpha for the total test was 0.89. These values are very satisfactory for an achievement test measuring a broad range of concepts and skills.

The inter-marker reliability for the marking of the written-response questions was also examined. The marking key for each question was prepared by the Student Evaluation Branch and then revised following discussion with four head markers. During the orientation session, teachers marked three common student responses for each question and discussed the awarding of marks. All teachers then marked an additional three student responses for each question so that the consistency of the marking procedures could be checked. At the beginning of each morning and afternoon marking session, all teachers marked two common student responses for each question. Any discrepancies were again discussed. For questions on those papers marked by all teachers, 86.8% of the marks awarded were in agreement, 13.2% deviated from the consensus mark by one mark, and none deviated by more than one mark. During the marking, one marker scored question 1, and a different marker scored questions 2 and 3 for each paper.

## Provincial Averages

The classification of examination questions according to subject matter topic and taxonomic level has been presented in Table 1, Chapter 2. Subtest scores were computed for each of the three subject matter topics, for the three taxonomic levels, and for the questions requiring the application of scientific process skills. Table 2 contains the provincial averages for these subtests and for the total examination. In each case, an average is given for the written-response questions, the multiple-choice questions, and the combination of the two (total). Averages are based on raw scores, which are the number of marks obtained on each subtest. The total marks possible is identified for the written-response and multiple-choice components of each subtest. For the multiple-choice component of each subtest, the average in per cent is also given.

Averages are based on 5688 students. Differences between total averages and component averages are due to rounding.

Table 2

Provincial Averages for Subtests

| Subtest | Total Marks Possible | | Raw Score Averages | | |
|---|---|---|---|---|---|
| | Written-Response | Multiple-Choice | Written-Response | Multiple-Choice | Total |
| Topics | | | | | |
| Energetics | 7 | 18 | 2.3 | 10.8 (60.0%) | 13.1 |
| Acids and Bases | 3 | 18 | 1.7 | 13.8 (76.7%) | 15.5 |
| Oxidation-Reduction | 5 | 19 | 1.9 | 13.0 (68.4%) | 14.9 |
| Process Skills | 0 | 7 | -- | 4.1 (58.6%) | 4.1 |
| Cognitive Levels | | | | | |
| Knowledge | 0 | 24 | -- | 16.5 (68.8%) | 16.5 |
| Application & Understanding | 15 | 24 | 6.0 | 16.5 (68.8%) | 22.5 |
| Higher Mental Activities | 0 | 7 | -- | 4.7 (67.1%) | 4.7 |
| Total Examination | 15 | 55 | 6.0 | 37.7 (68.5%) | 43.7 |

The standard deviation for the total examination was 11.6 raw score points.

The multiple-choice averages in per cent provide an indication of how well students performed within subject matter topics and taxonomic levels. The average for the multiple-choice questions on energetics is considerably below the overall average for the multiple-choice questions, while the average for acids and bases is considerably above the overall average. A possible reason for the low average on energetics is that this section of the program requires more complex computational procedures. The average for the process skill questions is also very low.

It is not meaningful to compare total subtest scores or written-response subtest scores across topics or taxonomic levels because of the uneven distribution of written-response questions. However, jurisdictions and schools can compare their averages to the provincial averages to help identify strengths and weaknesses in their programs.

## Comparison of Multiple-Choice and Written-Response Questions

The average mark attained on all multiple-choice questions was 68.5%, and the average on all written-response questions was 40.0%. It is not readily apparent why the written-response questions were answered so poorly.

In this section, each written-response question is discussed in relation to comparable multiple-choice questions.

In comparing written-response and multiple-choice items based on the same curricular concepts, there is little similarity in terms of item difficulty. Without exception the difficulty level of the written-response questions is lower than that of the corresponding multiple-choice questions. In most cases, the difference is considerable. This would appear to imply that students' difficulty with the written-response portion of the exam lies not in a general lack of comprehension of the concepts involved, but rather in the nature of the format of the required answer.

| Comparable Questions | Difficulty Levels |
|---|---|
| written-response 1 | 0.33 |
| multiple-choice 9 | 0.71 |
| multiple-choice 11 | 0.70 |
| multiple-choice 13 | 0.51 |
| multiple-choice 15 | 0.78 |
| multiple-choice 16 | 0.65 |

Despite the data presented, comprehension is perhaps a major problem with the unit on energetics. The marking session revealed that students have difficulty distinguishing among heat of formation, heat of reaction, and heat of combustion. The manner in which students attempted to answer question 1 seems to show that students memorize certain formulas and then do not fully understand why and when to use them.

This is not necessarily the case with the acids and bases chemistry unit. Questions 30 and 33(M-C) had difficulty levels of 0.80 and 0.90 respectively. Both questions are simple titration - stoichiometric problems involving a monoprotic acid and a monobasic base. Question 2(W-R), with an overall difficulty of 0.58, asked the students to perform an almost identical calculation again using a monoprotic acid and a monobasic base. This seems to indicate that students have some difficulty in presenting their solutions to a given problem.

| Comparable Questions | Difficulty Levels |
|---|---|
| written-response 2 | 0.57 |
| multiple-choice 30 | 0.80 |
| multiple-choice 33 | 0.90 |

Written-response question 3 also has a difficulty level that is lower than comparable multiple-choice questions. The questions listed below are related to the operation of an electrochemical cell.

| Comparable Questions | Difficulty Levels |
|---|---|
| written-response 3 | 0.38 |
| multiple-choice 45 | 0.61 |
| multiple-choice 46 | 0.44 |
| multiple-choice 50 | 0.72 |
| multiple-choice 52 | 0.79 |
| multiple-choice 54 | 0.71 |

Examination of student responses revealed that students appear to have difficulty showing their calculations in an orderly, chronological fashion using the correct units, and in determining the correct number of significant digits.

## Standard-Setting

Every effort was made to design a Chemistry 30 diploma examination that would be a valid and reliable measure of what students can be expected to know as a result of instruction in this course. A specific standard or level of expectation inherent in the examination was established through careful test development procedures. To ensure that each form of the examination administered in 1984 will be parallel to each other, the Student Evaluation Branch has adopted a process of standard-setting. One way to review the standards inherent in each examination is to involve classroom teachers in making judgments about the difficulty of the examination.

The teachers who marked the written-response portion of the examination reviewed the difficulty level of each question in terms of a borderline passing student (who merits 50%), a borderline "B" student (who merits 65%), and a borderline "A" student (who merits 80%). After teachers gave their initial judgments on question difficulty, they were given information about the actual distribution of students' examination marks. They were then given the opportunity to modify their judgments. Judgments from all teachers for all examination questions were pooled to determine the examination scores that teachers felt should be set equivalent to 50%, 65%, and 80%. For the January 1984 diploma examination, teachers felt that 46% should be raised to 50%, that 62% should be raised to 65%, and that 80% should be left at 80%. These cut-off scores are based on the judgments of 38, 19, and 19 teachers respectively.

## Transformation of Examination Marks

Since the cut-off scores obtained from the teachers' judgments were close to those that were intended, the chemistry marks were not transformed other than to change 48% and 49% to 50%. An additional adjustment was made to the examination marks so that students would not receive final blended marks of 48% or 49%.

## Relationship Between Examination Mark and School Mark

The provincial averages and standard deviations for the school-awarded mark, the transformed examination mark, and final blended mark are presented in Table 3.

Table 3

Summary Statistics for School Mark, Examination Mark, and Final Mark

| | School-Awarded Mark | Examination Mark | Final Blended Mark |
|---|---|---|---|
| Average | 66.0% | 62.7% | 64.7% |
| Standard Deviation | 13.3% | 16.4% | 13.8% |

The average school mark is 3.3% higher than the average examination mark after transformation. The correlation between school mark and examination mark was 0.72, which indicates a fairly close agreement in the rank ordering of the students based on the two sets of marks.

The percentages of students receiving A's, B's, C's, and F's are presented in Table 4 for the school mark, examination mark, and the final blended mark.

Table 4

Percentages of Students Receiving A's, B's, C's, and F's

| Score | School-Awarded Mark | Examination Mark | Final Blended Mark |
|---|---|---|---|
| A(80-100%) | 18.5 | 17.0 | 15.9 |
| B(65-79%) | 35.5 | 28.7 | 33.8 |
| C(50-64%) | 36.9 | 34.6 | 39.0 |
| F(0-49%) | 9.1 | 19.7 | 11.3 |

Results for Individual Questions

Multiple-Choice Questions

The percentage of students choosing each response for each question is given in Table 5. The correct response for each question is also identified.

Table 5

Results for Individual Multiple-Choice Questions

| | | Distribution of Response in %* | | | | | | Distribution of Response in %* | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Item | Key | A | B | C | D | Item | Key | A | B | C | D |
| 1 | A | 54.7 | 12.4 | 17.1 | 15.5 | 29 | B | 5.0 | 71.1 | 5.3 | 18.5 |
| 2 | B | 14.7 | 82.5 | 1.8 | 1.0 | 30 | C | 9.7 | 6.7 | 79.9 | 3.6 |
| 3 | D | 14.2 | 16.6 | 22.2 | 47.0 | 31 | D | 6.0 | 5.5 | 7.8 | 80.7 |
| 4 | A | 83.4 | 10.5 | 2.8 | 3.2 | 32 | C | 2.3 | 1.5 | 84.3 | 11.9 |
| 5 | C | 9.4 | 13.2 | 63.6 | 13.7 | 33 | C | 3.3 | 4.0 | 89.6 | 3.0 |
| 6 | B | 10.2 | 70.8 | 10.9 | 7.8 | 34 | A | 87.3 | 7.0 | 3.2 | 2.4 |
| 7 | A | 62.8 | 7.7 | 11.5 | 17.8 | 35 | A | 56.3 | 20.9 | 12.7 | 10.1 |
| 8 | D | 12.6 | 15.3 | 18.5 | 53.5 | 36 | C | 10.5 | 11.7 | 67.6 | 9.9 |
| 9 | A | 70.7 | 11.2 | 15.4 | 2.4 | 37 | B | 17.3 | 59.5 | 10.8 | 12.4 |
| 10 | D | 13.6 | 15.2 | 12.0 | 59.0 | 38 | C | 4.4 | 6.7 | 83.3 | 5.5 |
| 11 | D | 11.3 | 13.7 | 4.7 | 70.2 | 39 | A | 89.0 | 2.2 | 4.1 | 4.7 |
| 12 | B | 18.3 | 50.0 | 16.0 | 15.2 | 40 | C | 7.6 | 14.0 | 69.4 | 8.8 |
| 13 | A | 50.7 | 16.5 | 23.5 | 8.9 | 41 | B | 12.9 | 75.8 | 9.6 | 1.4 |
| 14 | A | 42.5 | 10.9 | 27.6 | 18.8 | 42 | A | 75.9 | 7.8 | 7.6 | 8.6 |
| 15 | D | 7.2 | 6.5 | 8.6 | 77.6 | 43 | B | 7.0 | 76.8 | 11.0 | 5.1 |
| 16 | C | 5.9 | 25.9 | 65.2 | 2.8 | 44 | A | 50.6 | 30.3 | 8.5 | 10.6 |
| 17 | B | 29.3 | 39.6 | 12.6 | 18.4 | 45 | D | 13.7 | 6.9 | 18.8 | 60.5 |
| 18 | B | 12.3 | 39.0 | 40.3 | 7.6 | 46 | C | 14.3 | 26.5 | 44.2 | 14.9 |
| 19 | D | 4.8 | 27.9 | 7.1 | 60.1 | 47 | C | 8.1 | 13.3 | 55.4 | 22.9 |
| 20 | D | 2.4 | 4.8 | 15.9 | 76.9 | 48 | B | 7.1 | 63.2 | 8.6 | 20.9 |
| 21 | B | 9.8 | 51.1 | 12.8 | 26.3 | 49 | D | 8.1 | 8.9 | 5.1 | 77.7 |
| 22 | C | 6.9 | 11.2 | 77.2 | 4.7 | 50 | B | 16.7 | 72.0 | 5.6 | 5.5 |
| 23 | C | 1.7 | 1.2 | 93.4 | 3.7 | 51 | D | 19.0 | 4.6 | 6.8 | 69.4 |
| 24 | D | 6.2 | 2.9 | 16.4 | 74.6 | 52 | B | 11.4 | 78.8 | 5.7 | 4.0 |
| 25 | C | 7.3 | 7.8 | 82.1 | 2.6 | 53 | D | 9.4 | 12.4 | 6.2 | 71.8 |
| 26 | B | 3.7 | 80.4 | 12.2 | 3.7 | 54 | A | 70.5 | 15.5 | 5.8 | 7.9 |
| 27 | B | 2.9 | 90.9 | 2.1 | 4.0 | 55 | A | 59.3 | 23.6 | 9.5 | 6.2 |
| 28 | A | 77.7 | 10.5 | 7.1 | 4.6 | | | | | | |

*The sum of the percentages for each question is less than 100% because the No Response category is not included. This category less than 1.5% for all questions.

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Written-Response Questions

The percentage of students awarded each ma
Table 6.

### Table 6

### Distribution of Marks for Written-Response Questions

| Question Number | Percentage of Students Obtaining Each Mark | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | NR* | 0 | 1 | 2 | 3 | 4 | 5 | 6 | 7 |
| 1 | 1.1 | 10.3 | 17.5 | 26.1 | 26.9 | 10.5 | 4.7 | 2.5 | 0.4 |
| 2 | 4.6 | 14.3 | 19.3 | 30.4 | 31.5 | | | | |
| 3 | 2.7 | 21.7 | 22.2 | 19.5 | 14.9 | 9.0 | 10.0 | | |

*NR - No Response

The total number of marks possible, the average mark awarded to students, and the difficulty level for each written-response question are summarized in Table 7. The difficulty level is the average divided by total marks possible.

### Table 7

### Average Marks Awarded for Written-Response Questions

| Question Number | Total Marks | Average | Difficulty Level |
|---|---|---|---|
| 1 | 7 | 2.3 | 0.33 |
| 2 | 3 | 1.7 | 0.57 |
| 3 | 5 | 1.9 | 0.38 |

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